Model Based Risk Assessment: Foundations and Applications

Ali Mosleh
UCLA School of Engineering and Applied Science
mosleh@ucla.edu

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Definition of Risk

- Risk is usually associated with the uncertainty and undesirability of a potential situation or event

Risk = Uncertainty and Undesirability

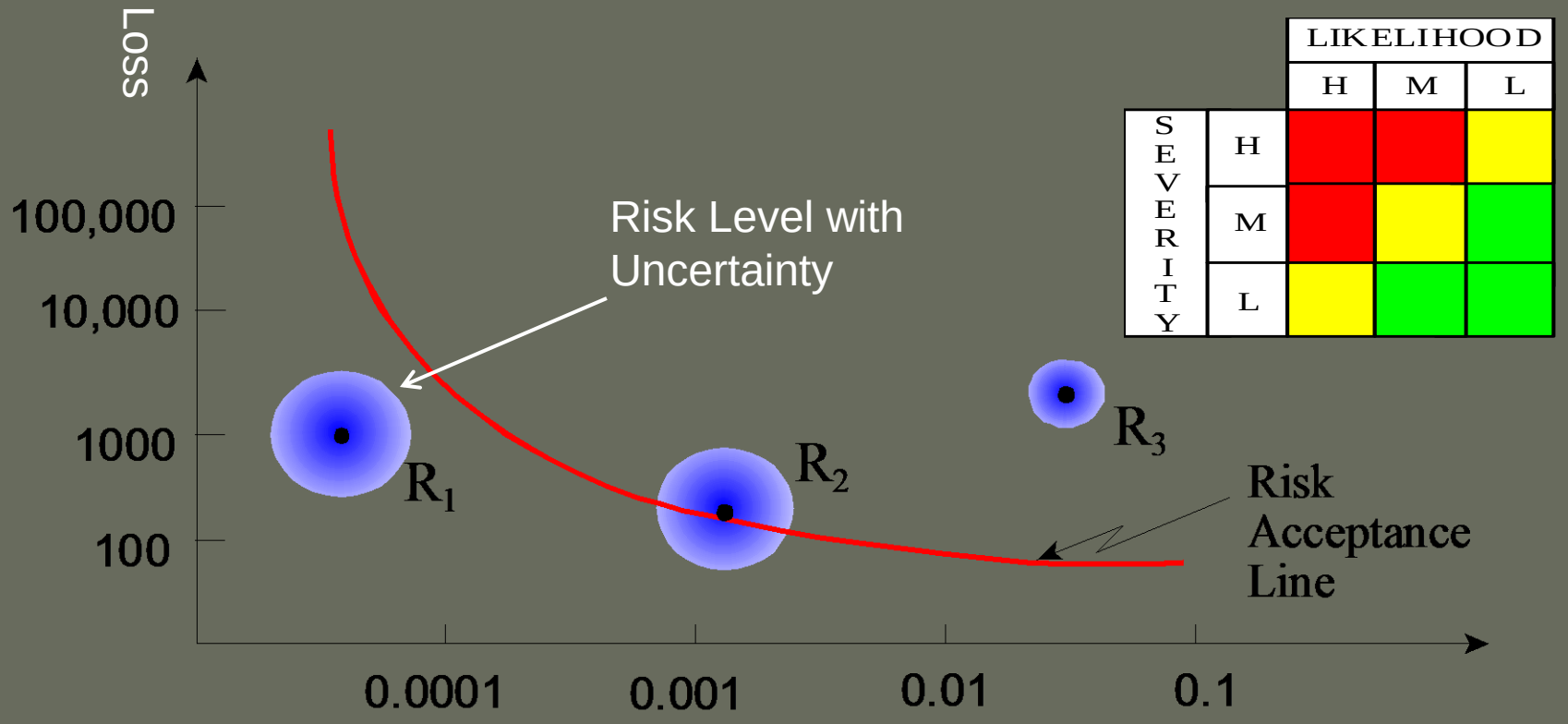
- In order to have a risk situation, both elements must be present
- Metrics

Risk = Likelihood and Severity

Three Questions of Risk Analysis

- What can go wrong?
- What are the consequences ?
- How likely are they?

Input to Decision Making

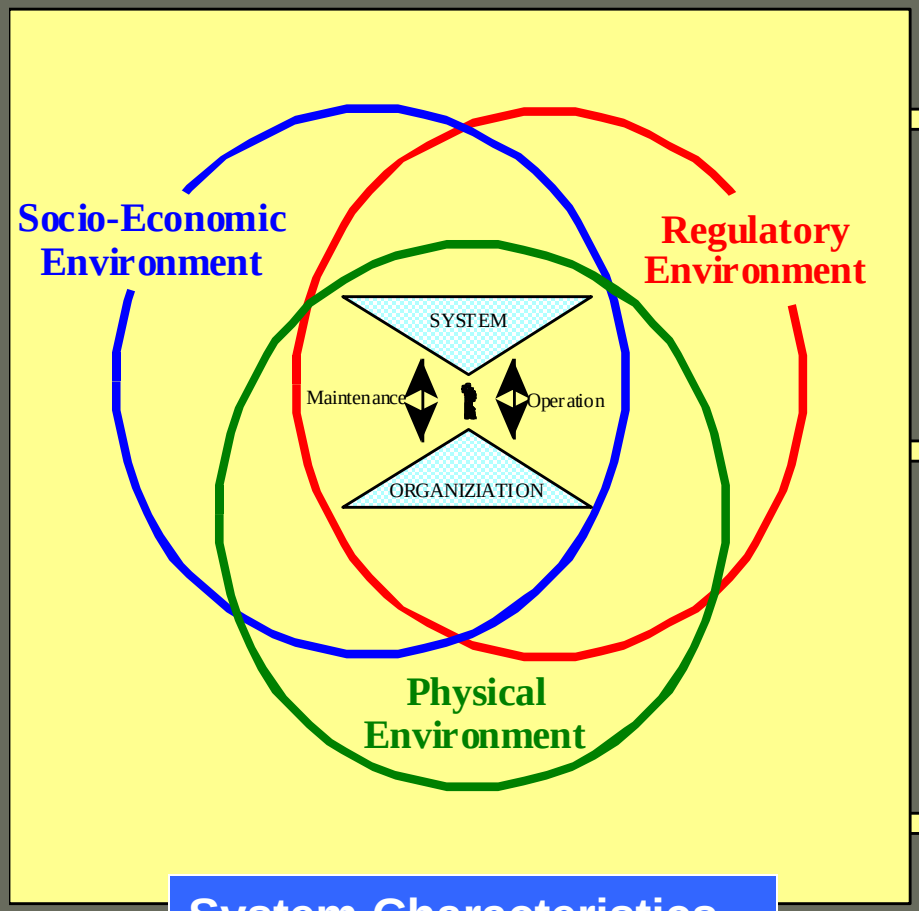


***Hazard Category* R1**

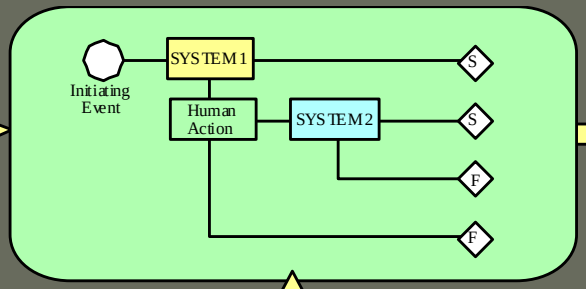
***Hazard Category* R2**

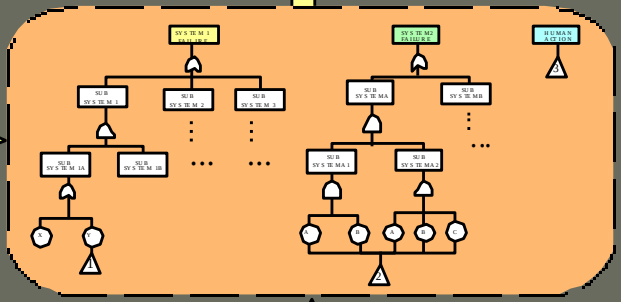
***Hazard Category* R3**

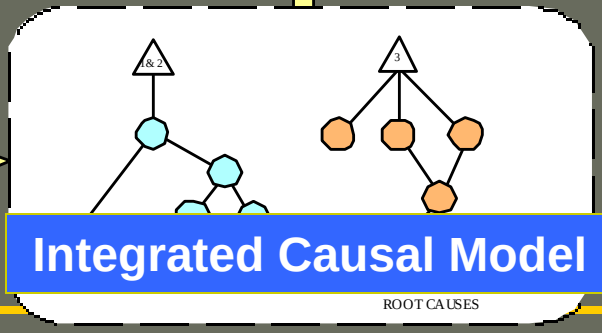
Model-Based Approach



System Characteristics

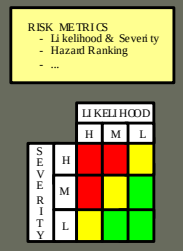




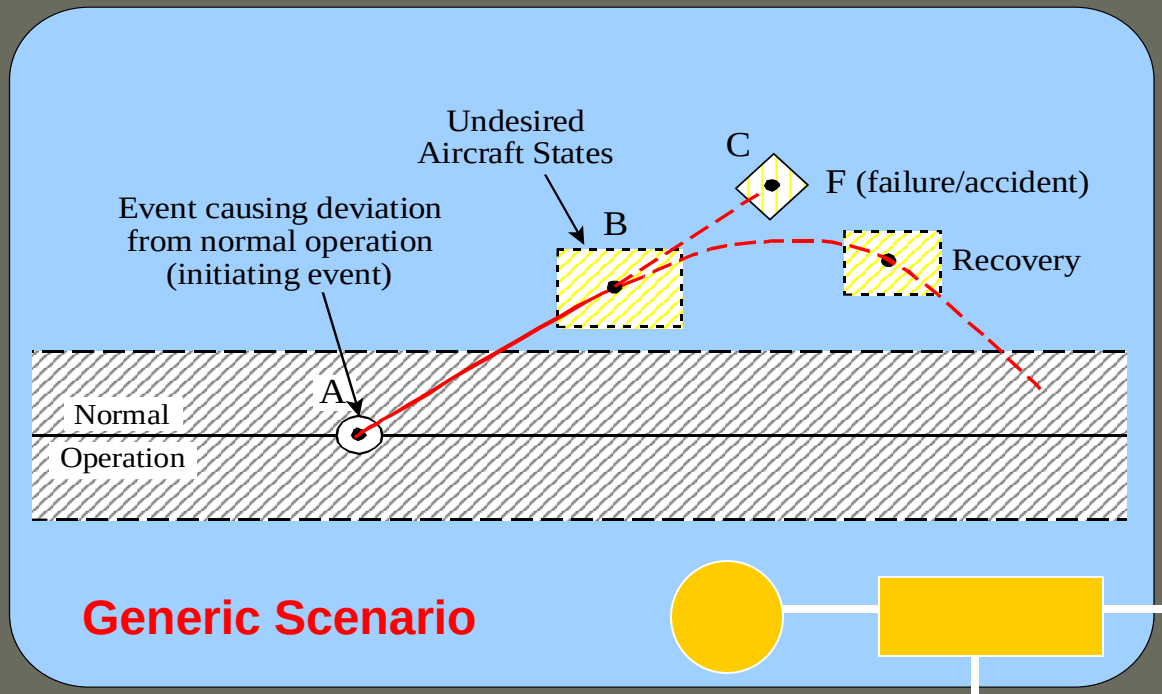


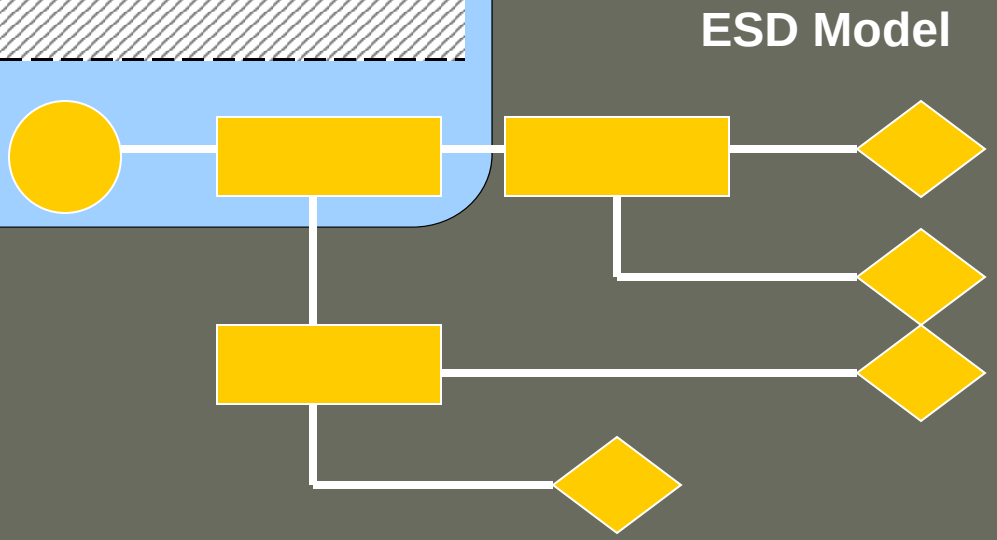
Integrated Causal Model

ROOT CAUSES

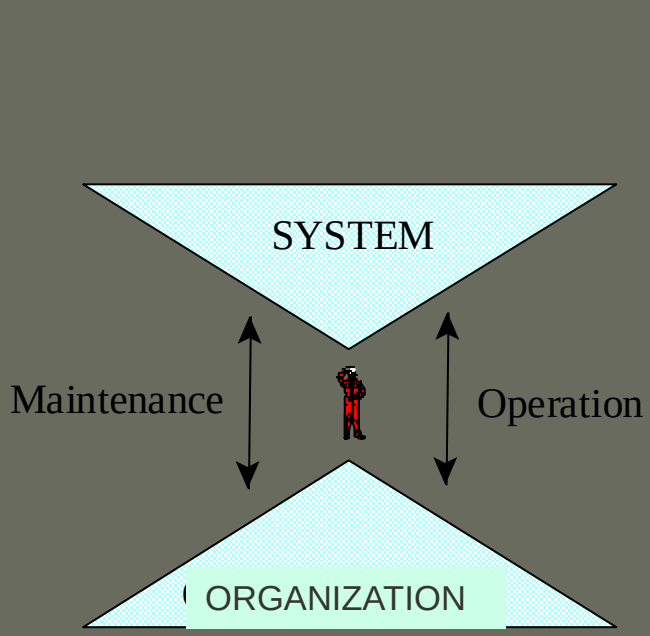


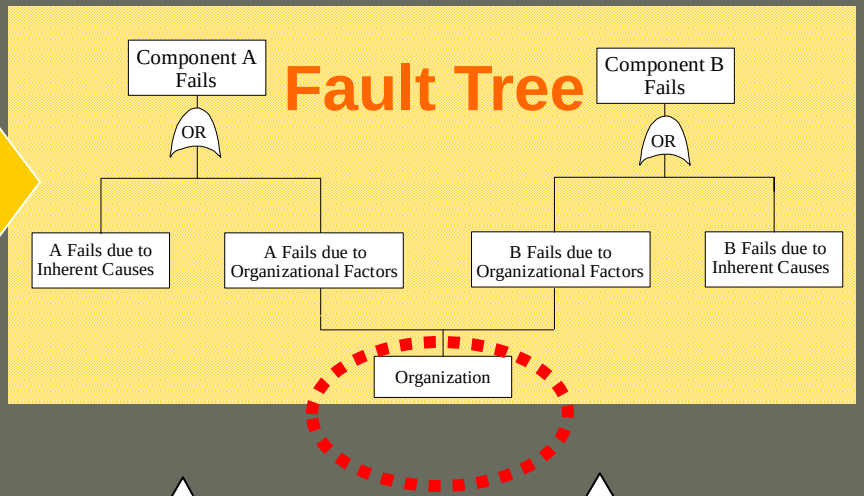
Anatomy of Scenario-Driven Risk Analysis

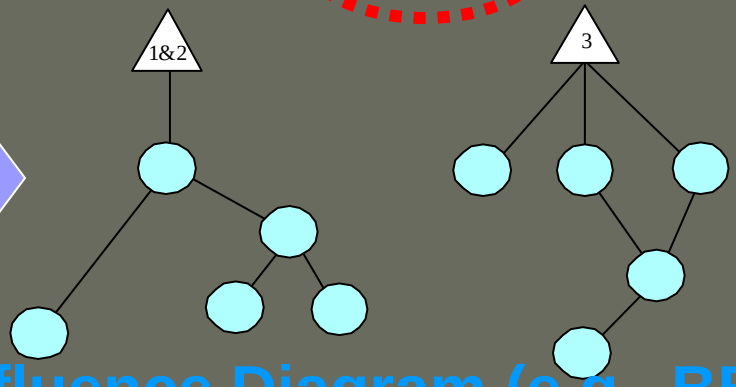




Causal Details through Fault Trees and Influence Diagrams

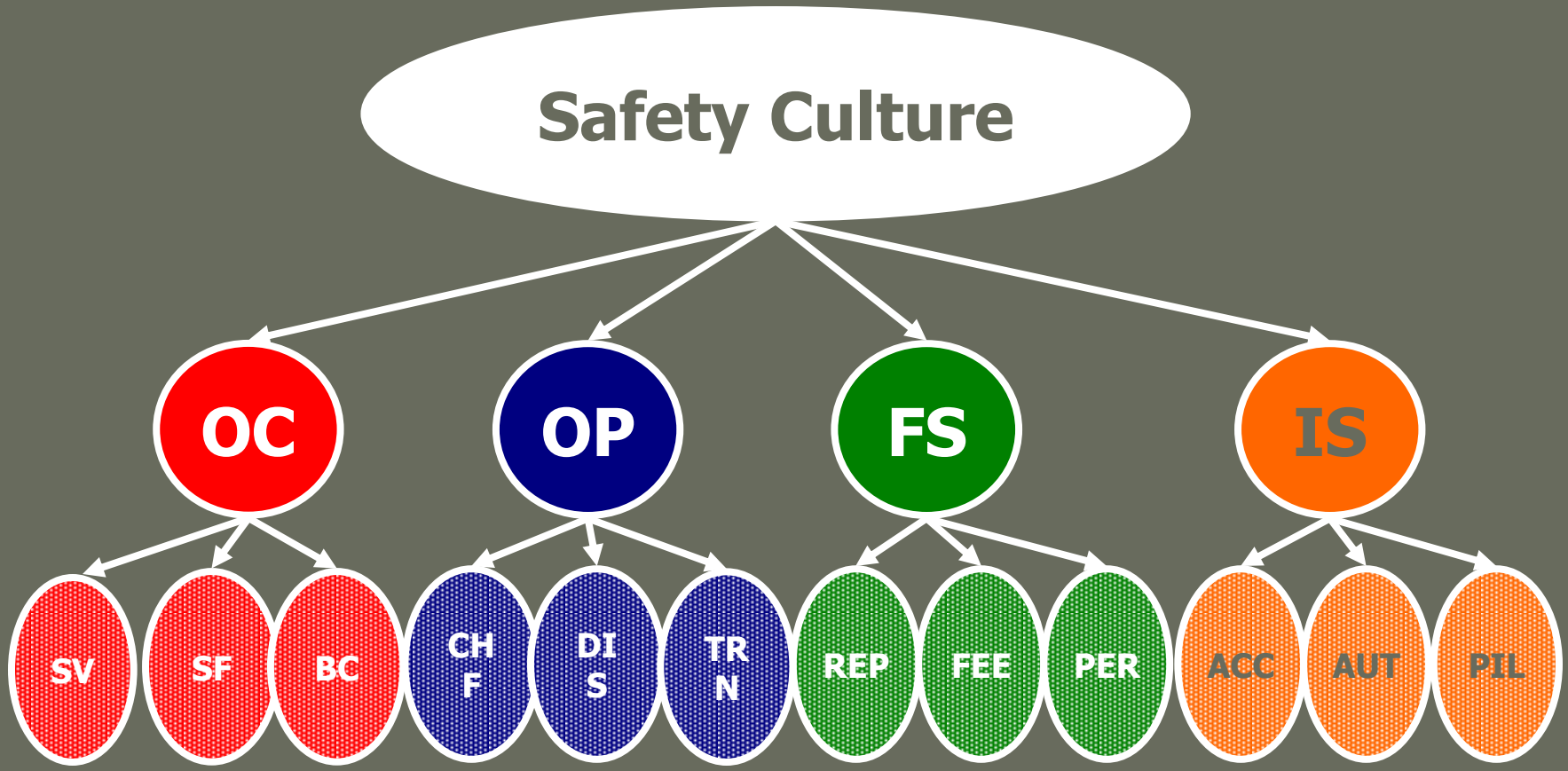






Influence Diagram (e.g., BBN)

Incorporating Soft Causal Factors (e.g., Safety Culture Factors)

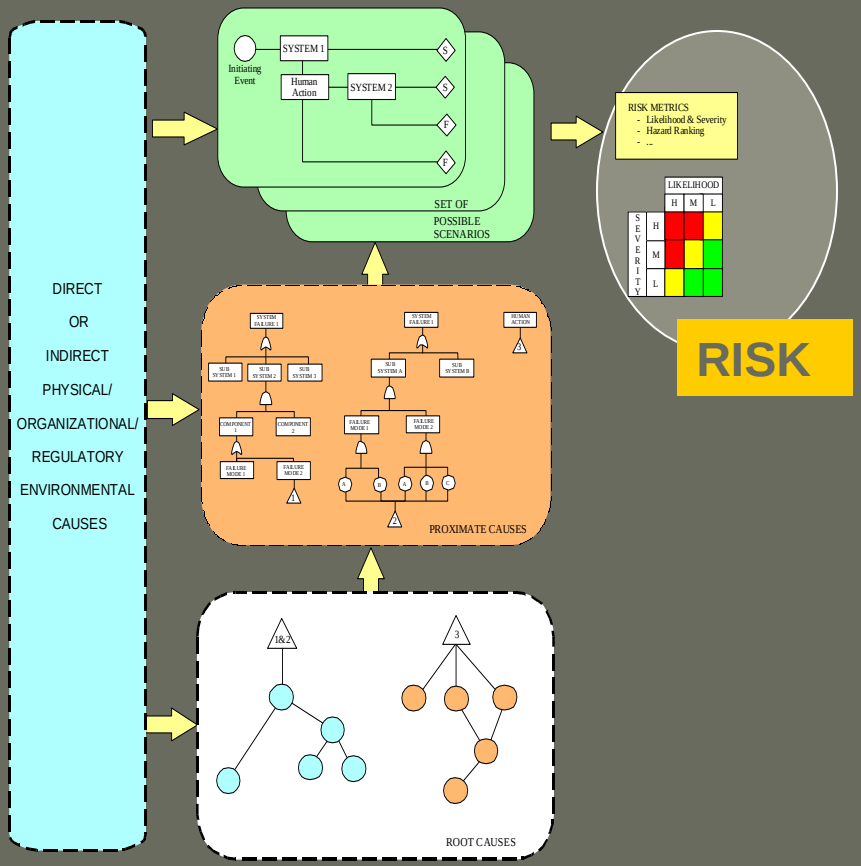


Application Areas

- Analysis of Hazards
  - Identification
  - Ranking
- Accident/Incident Analysis
  - Identifying common root causes
- Identification and Quantification of Safety Indicators
  - Calculation of conditional risk for various safety indicators
- Analysis of Precursor Events ■

Risk Analysis

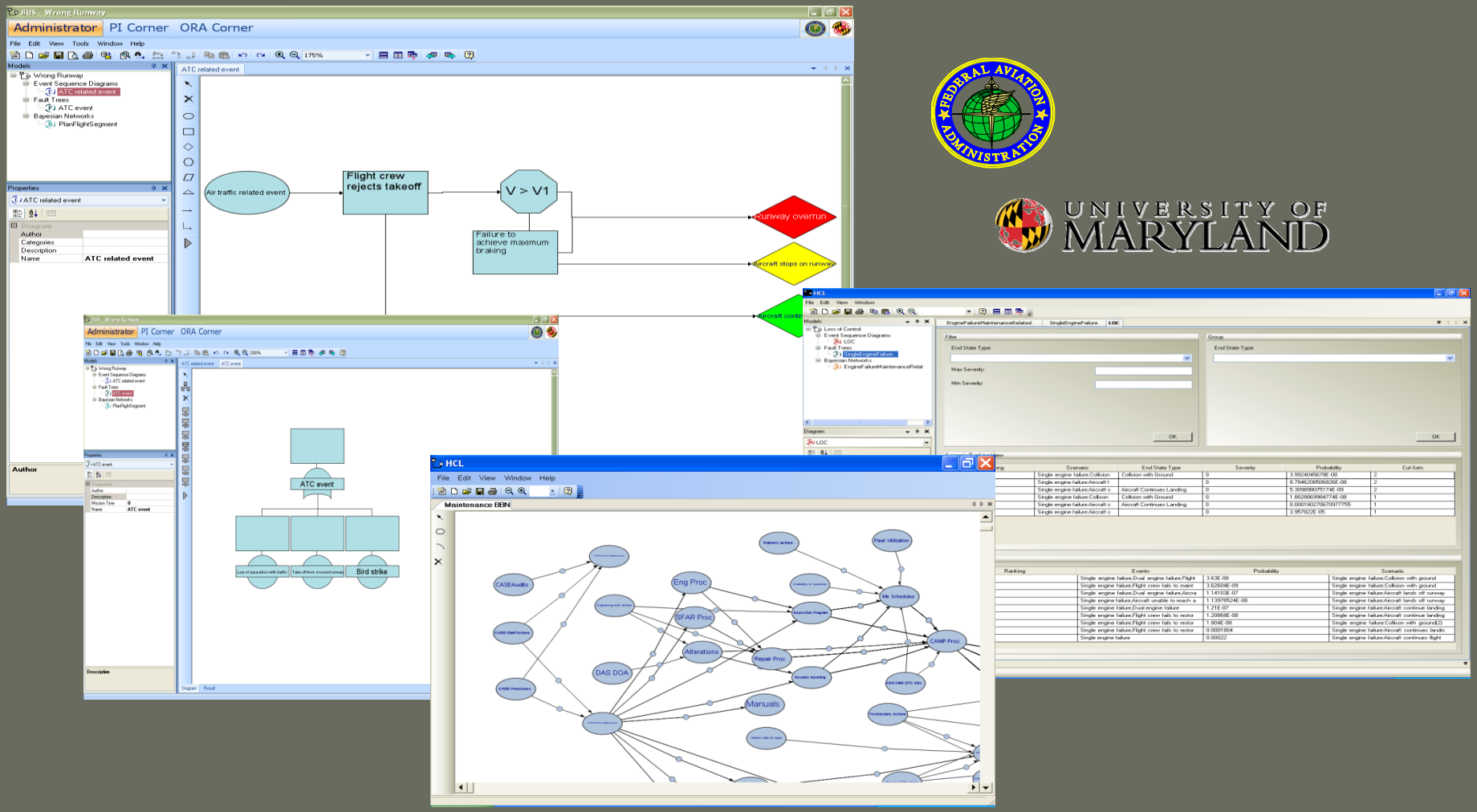
Risk Model (Scenario Analysis)



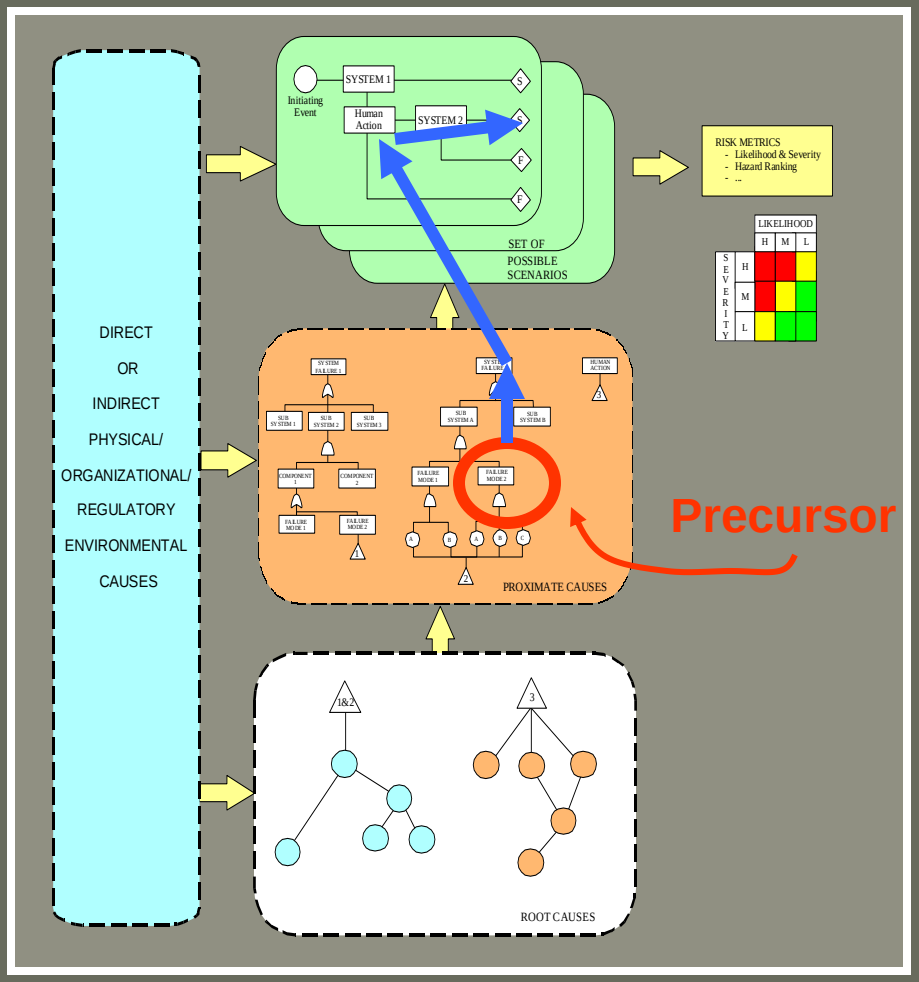
Quantitative Ranking of Risks

ET Scenario	Min Cut Sets	Prob./ Freq	Cutset Freq.	Total Frequency
Scenario 3	IE	1.00E-02		
	/A1	1.00E-05	1.00E-07	
Scenario 9	IE	1.00E-02		
	/A2	1.00E-01		
	PP	1.00E-04	1.00E-07	
	IE	1.00E-02		
	CN	1.00E-04		
	/A2	1.00E-01	1.00E-07	
	IE	1.00E-02		
	/A2	1.00E-01		
	P1	1.00E-03		
	P2	1.00E-03	1.00E-09	
Scenario 6	IE	1.00E-02		
	L	1.00E-01		
	/A2	1.00E-01	1.00E-04	
	IE	1.00E-02		
	/L	9.00E-01		
	V2	1.00E-03		
	/A2	1.00E-01	9.00E-07	
	IE	1.00E-02		
	V1	1.00E-03		
	/A2	1.00E-01		
	/L	9.00E-01	9.00E-07	
Sum				**1.02E-04**

IRIS Hybrid Platform



Precursor and Event Assessments



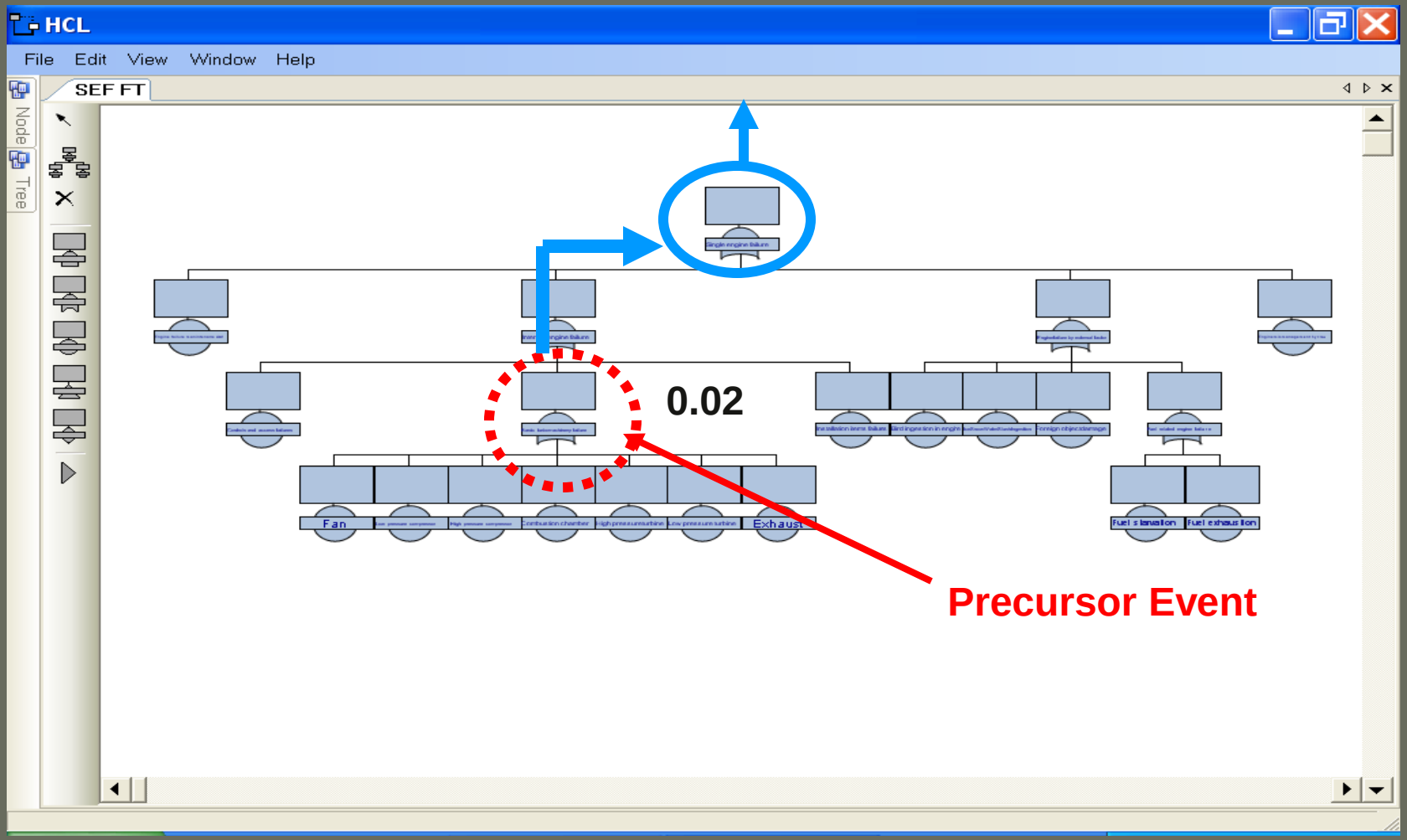
- The risk level is calculated as

$$R = \Phi * P(Accident \mid Precursor)$$

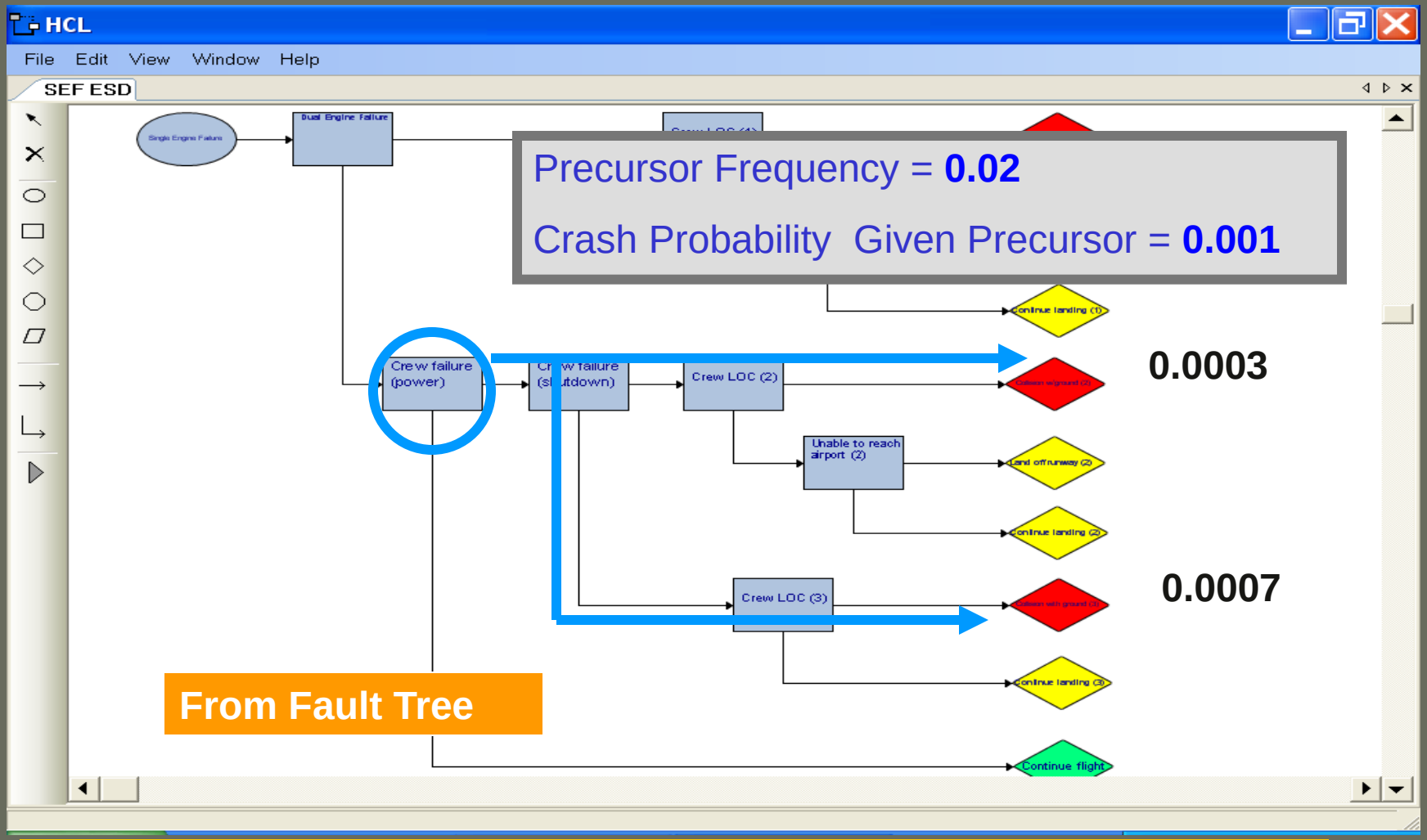
- Φ is the frequency of the precursor event of a certain type

- If there are other precursors the total risk is calculated by summing over individual precursor risks

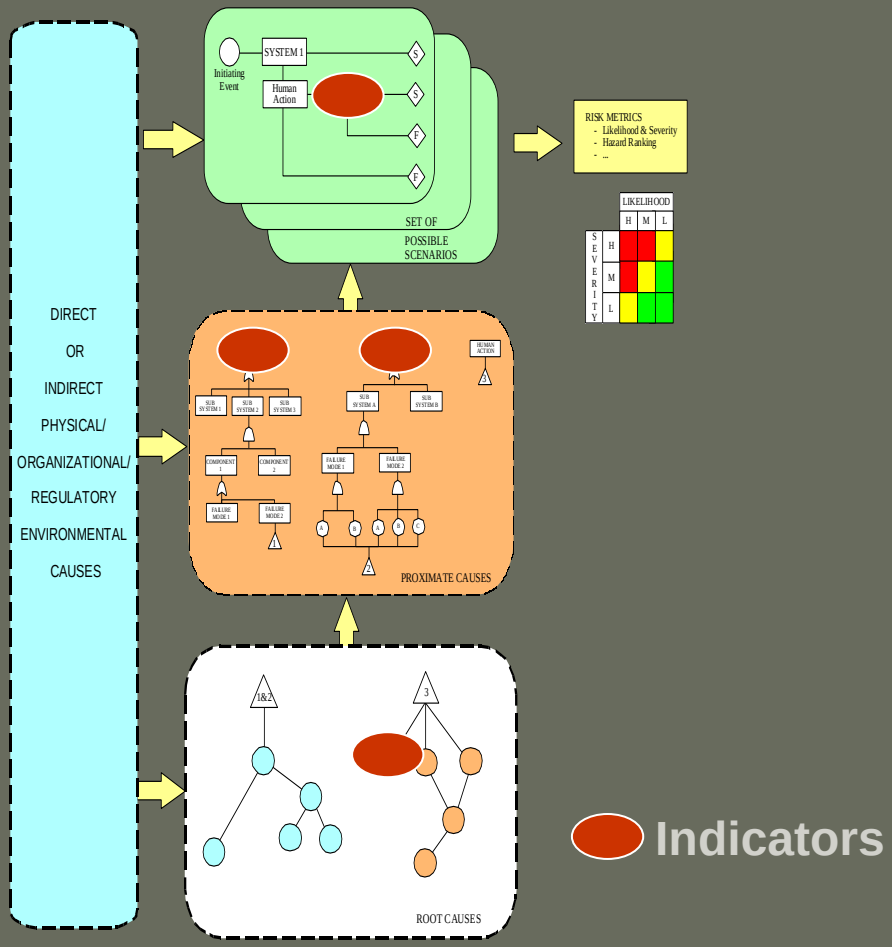
Precursor Event Assessment (1/2)



Precursor Event Assessment (2/2)



Selecting and Justifying Safety Performance Indicators



	Indicator	Frequency	"Risk Weight"
1	SI-1	3	0.02
2	SI-2	0.1	0.7
3	SI-3	1	0.01
4	SI-4	0	0.5
	..		
	..		
N	SI-N	φ_N	P_N

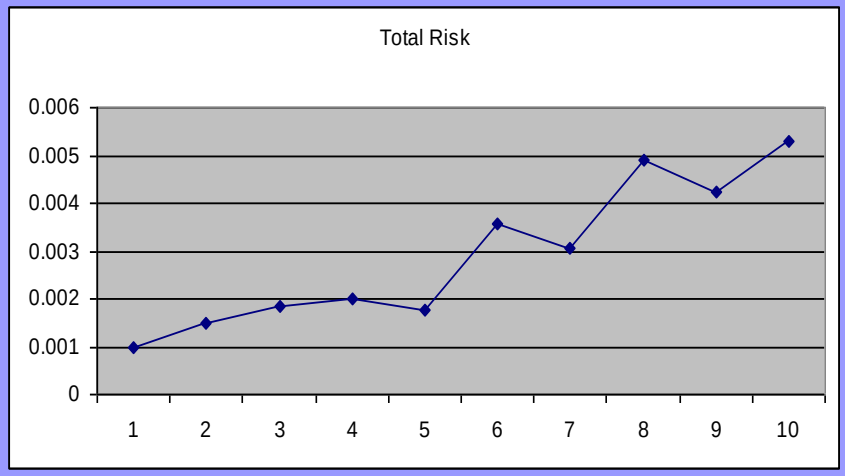
Monitoring Safety Using Performance Indicators

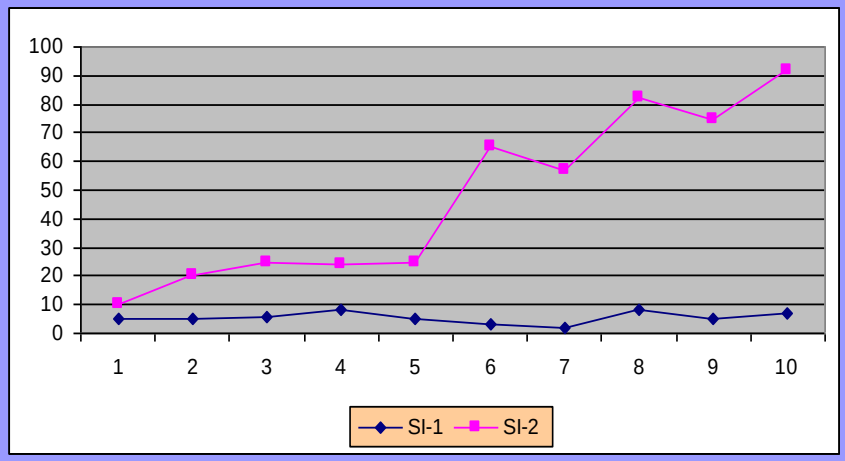
	Indicator	Freq.	"Risk Weight"
1	Engine Failure	3	0.02
2	Hydraulic System Failure	0.1	0.70
3	Missed Approach	1	0.01
4	…..	0	0.5

Select Indicators to Plot

Select Airline

Total Risk





Applications

- **Nuclear**
  - PRA, Risk Monitor, Outage Planning, Precursor Analysis, Even Assessment, Regulatory Oversight
- **Aviation**
  - SASO, Risk Informed Inspection, Safety Indicators
- **Space**
  - Mission Assurance, QRA, Precursor, Upgrades, Operational Decisions, Design Trade Studies (Shuttle, ISS, ESA,…)
- **Petro-Chemical**
  - QRA, Safety Assessment, Precursor Analysis